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Distribution Pricing

ENERGY TRANSPORTATION COSTS TYPICALLY make up a quarter of consumers' electricity bills, and most of this amount (90% in the United Kingdom, 75% in Brazil and Spain, and 60% in India, for example) is due to energy transportation through the distribution network. This cost could escalate over the next few decades as distributed energy resources are expected to grow substantially in response to the financial incentives many governments have created for renewable and efficient generation to meet their CO_2 reduction targets.

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The cost, however, can be minimized if distribution network operators (DNOs) have an appropriate distribution pricing scheme to influence existing and new network users concerning when and where to use the network. Through an economic pricing scheme, DNOs could take the lead in promoting efficient investment and effective use of distribution networks for the long-term interests of consumers and society as a whole.

Furthermore, economically efficient pricing is vital in encouraging significant growth in distributed energy resources (DERs), as DNOs can be rewarded for reducing network losses and building new infrastructure, and also for reducing the cost of energy supply. Moreover, with advances

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in smart-grid technologies, distribution pricing has a greater role in sending economic signals to network users encouraging them to respond to real time energy and network needs.

The Current Distribution Pricing Framework

Most of the tariff structures and charging methodologies currently in practice for the distribution system were developed in the 1970s and 1980s; they cannot serve either to promoting network efficiency or to encourage sustainability for the following reasons:

- ✔ The majority of the distribution pricing methodologies in practice were designed for a passive system with little embedded generation, microgeneration, and demand responses.
- ✔ The majority of the pricing methodologies for distribution systems are not cost reflective—that is, they do not reflect the costs/benefits that embedded or microgeneration might bring to the distribution network and energy supply. As a result, the pricing system cannot efficiently influence how and when network users should use the system.
- ✔ There is a lack of a commonly accepted pricing structure across the industry worldwide. As a consequence, there is little consensus in distribution pricing models among different countries, or among DNOs within the same country.
- ✔ As the boundary between transmission and distribution networks becomes increasingly vague, there is still a huge gap between transmission and distribution pricing methodologies.

Many regulators around the world are concerned that such a structure can neither minimize investment costs nor optimize the use of the current and future distribution energy systems.

Are We Ready for the Smart Grid?

Moreover, the electricity supply industry is undergoing a transformation to promote greater interactions between network users and the grid through smart monitoring, communication, and management systems. Consequently, the pricing mechanism is the key to ensuring the success of the smart grid. Yet there is no established practice or common pricing principle that can best serve the industry in the coming period of great change. Instead, tariff structures and charging methodologies differ vastly from one country to another and from one distribution network to another within the same country.

Distribution Pricing Process

The design of a distribution pricing scheme can generally be separated into two steps: establishing the regulatory revenues (the allowed revenue over a certain period of time) and allocating this allowed revenue from network users; revenue recovery comes through the connection and the use-of-system (UoS) pricing and tariff structure.

The regulatory revenue of distribution utilities is usually established in the tariff reviewing process, which usually occurs in a four-, five- or eight-year period. This revenue is the total allowed costs for operation, maintenance, and investment that DNOs require to provide the distribution services in

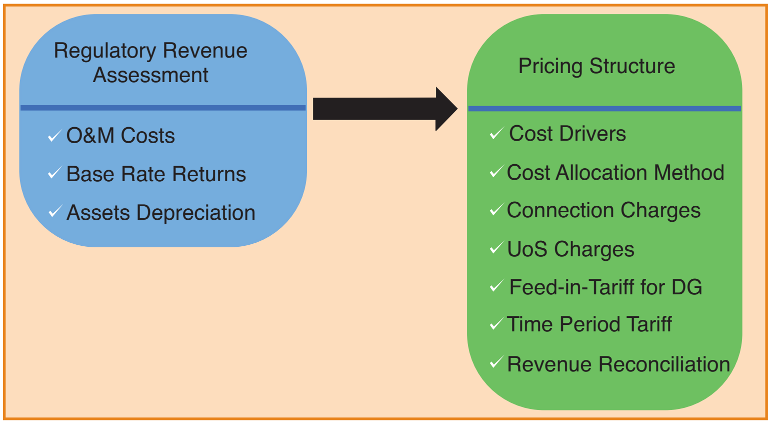

figure 1. Distribution network pricing process.

their designated distribution areas. In this process, the regulatory agency typically calculates the total required revenue on the basis of operation and maintenance (O&M) expenditure (OPEX) and capital expenditure (CAPEX), then combines these together to calculate a total expenditure (TOTEX). Regulated revenue is designed to cover efficient O&M costs, base rate returns, depreciation of assets, and other costs.

The pricing structure represents the process that DNOs use to collect money from network users to match the regulatory allowed revenue. In other words, the pricing structure dictates how DNOs allocate the allowed revenue among network users: suppliers, large industrial customers, and distributed generators (DGs). This generally involves a two-step process.

- ✔ First, network charges are set from the charging methodology approved or used by the industry regulator, such as Office of Gas and Electricity Markets in the United Kingdom and Agência Nacional de Energia Elétrica in Brazil.
- ✔ Next, during revenue reconciliation, charges are converted into tariffs, scaling tariffs up or down such that revenue recovery exactly matches regulatory revenue.

Figure 1 summarizes the distribution network pricing process and illustrates its key aspects.

The Survey

A survey was conducted to compare distribution pricing structures among seven countries (see Figure 2). Survey questions relate to key aspects of each country's pricing mechanisms and incentives for using distribution systems.

What Are the Voltage Levels of the Distribution Network?

The voltage levels in kilovolts of the distribution networks differ across the seven countries, and even within countries in Europe and Latin America (see Table 1 and Figures 3 and 4).

Is There Any Locational Pricing Structure in the Distribution Network?

Until very recently (2007), there were no locational pricing structures within distribution networks anywhere in the world. There were, however, different sophistications for nonlocational UoS charges.

For the United Kingdom and Brazil, tariffs differ at different voltage levels within a distribution network. For Chile, tariffs differ on the basis of density and asset type. For countries like Germany, tariffs do not differ between voltages within the same network, but they do differ between

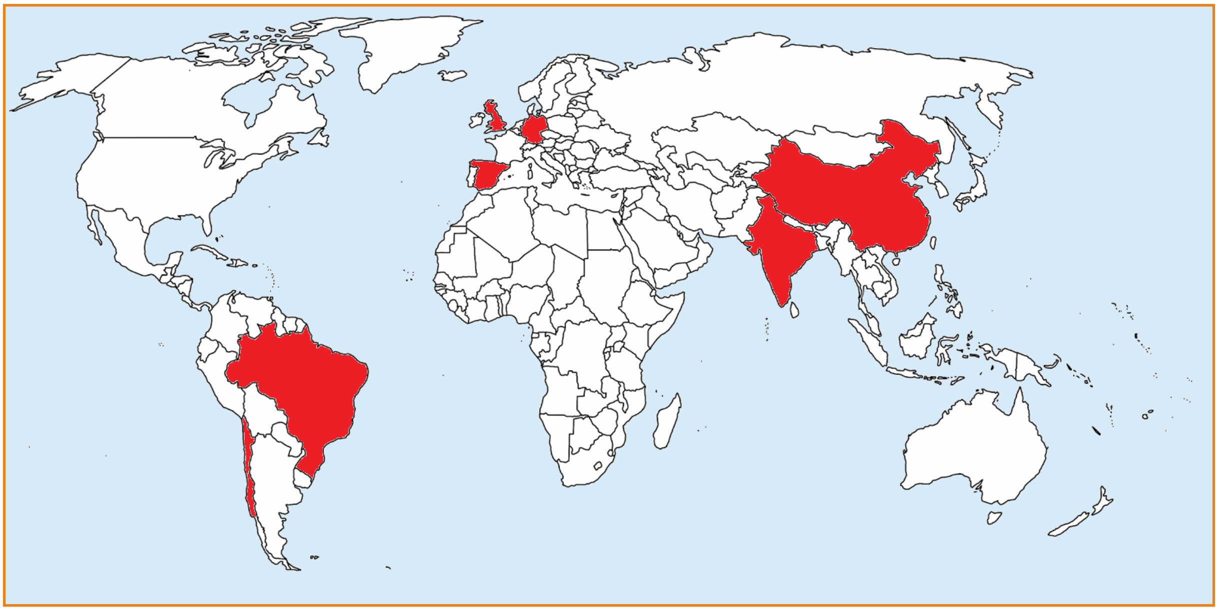

figure 2. The seven countries participating in the survey: Brazil, Chile, China, Germany, India, Spain, and the United Kingdom.

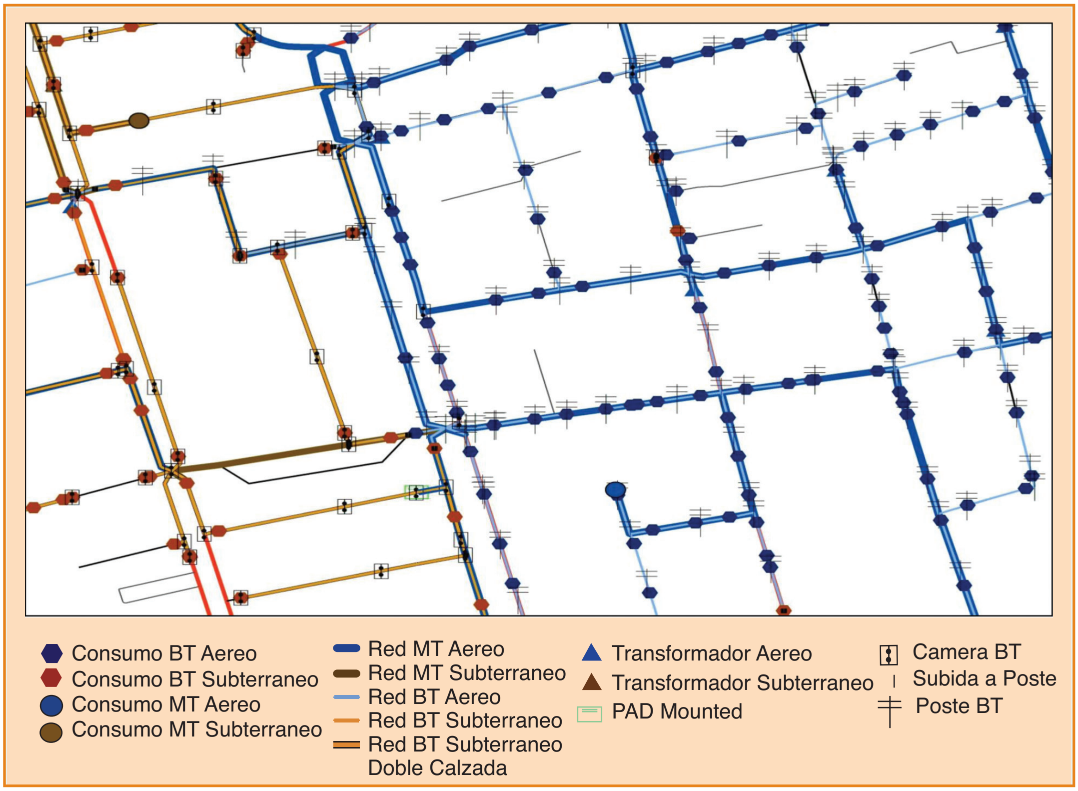

figure 3. MV network in Santiago, Chile. (Reprinted by permission of Systep.)

different distribution networks, reflecting diverse underlying cost at the regional level. Moreover, in countries like Spain and India, tariffs are the same for all customers connected to the same voltage level.

Post-2007, the United Kingdom and Brazil lead the way in introducing locational charges at the extra-high voltage (EHV) distribution level. Both countries' reform is driven by anticipated substantial growth in DGs. The regulators of the two countries are concerned by the lack of incentives for DGs to locate at economically efficient places that will best utilize the existing network and minimize the requirement for costly network upgrading. However, for demand, high-voltage (HV) and low-voltage (LV) networks still use the distribution reinforcement model (DRM) approach, where customers at the same voltage level are subject to the same incremental cost regardless of their locations. The incremental cost is based on the historical cost in accommodating demand increments.

In Brazil, additional regulatory concern arose from DGs' migration tendency to the transmission networks, as they are financially better off with locational transmission charges.

In Germany, there are no locational signals for generators or load. Network tariffs differ among network operators because of different underlying costs, but not due to any systematic geographical component. DGs receive a premium for avoided network charges of higher voltage levels. Avoided network charges are calculated per regional network—that is, without systematic locational signals. Contribution-to-network costs (*Baukostenzuschüsse)* charged from newly connecting generation or load are intended to favor needs-based network expansion and avoid overdimensioned network capacity. This does not convey locational signals

table 1. A summary of distribution voltage levels .

Voltage Level	United Kingdom	Germany	Spain	Brazil	Chile	India
Extra-high voltage (EHV)	132, 33, 22	110	220, 132, 72.5, 66, 45, 36	138, 88, 69, 34.5	N/A	132, 33
Medium or high voltage (MV or HV)	11, 6.6	20, 10	15, 20	13.8	23	11
Low voltage (LV)	0.415	0.4, 0.23	0.4	0.22	0.38	0.44

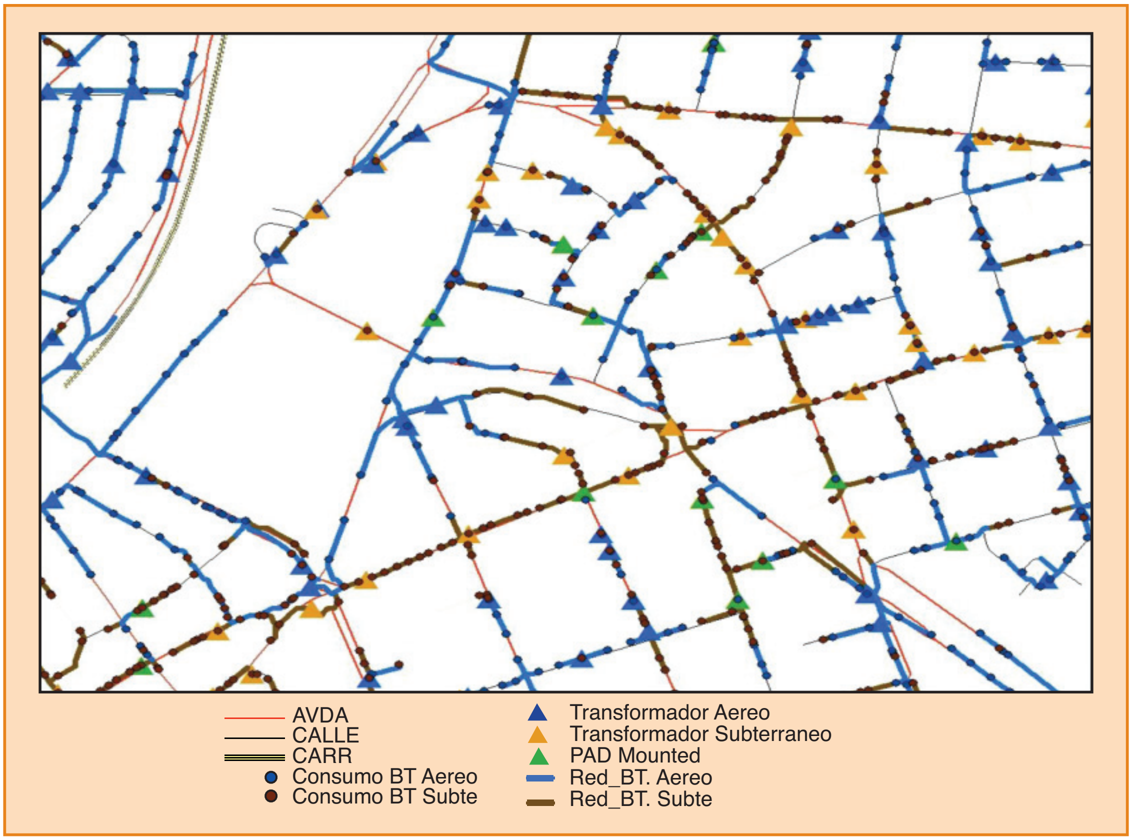

figure 4. LV network in Santiago, Chile. (Reprinted by permission of Systep.)

either, as calculations can be based on average cost of similar cases and does not necessarily relate to concrete and prompt network investment.

In India, the tariff structure varies across different states. In any given state, the pricing structure is uniform for a given type of customer. No geographical differentiation in tariff exists. Connection charges do reflect the impact of location from the connection point, but there is currently absolutely no locational signal to grid users.

In Spain, as in India, there is no geographical differentiation in tariffs, either for demand or for generators. This is a very delicate and controversial issue in Spanish regulation. Furthermore, there are no differences in tariffs for different distribution companies. That is, tariffs are the same for all customers connected to the same voltage level all over Spain.

In China, there is no locational pricing. However, for the generation side, a benchmark price system is used to determine the price of newly installed generators.

What Cost Is Used in Your Charging Calculation? Is the Marginal Cost or Long-Run Incremental Cost Used? How?

In the United Kingdom, DNOs can choose between two methodologies to charge for the use of their EHV networks: long-run incremental cost pricing (LRIC) and forward cost pricing (FCP). LRIC seeks to quantify the additional costs/benefits to future network investment from a nodal increment—that is, either injecting or withdrawing power from a node. FCP sets prices that can recover the projected network cost over next ten years.

FCP has a number of components:

- ✔ FCP demand charges are based on incremental cost to accommodate future demand within a network group.
- ✔ FCP generation credits are derived on the same basis.
- ✔ FCP generation charges are the average cost of the ten years' increment cost—that is, the total incremental cost divided by the total generation volume over the ten year period.

For HV/LV networks, the coming year's reinforcement cost to accommodate demand growth is forecast based on the present year's expenditure.

In Brazil, average long-run incremental costs are determined for each voltage level: the ratio of future investment costs and load growth are set in terms of present value. This structure is then used for allocating the total required revenue among the voltage levels. This structure is applied to all users except for the generators connected to 138 kV and 88 kV.

In India, embedded costs of networks comprise interest on debt, return on equity, depreciation, operation and maintenance expenses, and interest on working capital.

With advances in smart-grid technologies, distribution pricing has a greater role in sending economic signals to network users.

Marginal and incremental costs are not reflected in cost allocation. Cost allocation is based on the peak conditions existing in a year.

In Germany, historical cost of the last completed accounting year is used both for the benchmark, which is the base for the revenue cap in each five-year regulatory period and for starting prices. Cost components include depreciation, interest on debt, return on equity, and cost for network losses. There is no forward-looking component in the calculation. However, network operators can apply for investment budgets for planned investment. The costs are socialized onto the end users.

In Spain, access tariffs for transmission and distribution networks are set by the government, taking into account recommendations from the Spanish regulatory body, the Markets and Competence National Commission (CNMC). The CNMC tariff methodology is based on assigning costs to consumers according to the cost-causality principle. Thus, network costs are first allocated to energy and capacity, taking into account the results of a reference network model. After that, energy and capacity costs by voltage level are assigned to different time periods: energy costs are assigned proportionally to energy consumption, and capacity costs are assigned to specific hours in the year (between 876 and 1,500 hours) with the highest demand in each voltage level. Finally, for each time period and voltage level, energy costs are allocated to consumers according to their energy consumption and capacity costs based on their peak demand in the corresponding time period. A cascade network model is used to assign the costs of the different voltage levels between the consumers connected to the different voltage levels. Commercial costs are assigned as a fixed charge per customer, and other costs are assigned to create as little distortion as possible.

In Chile, distribution networks are assumed to be designed to supply under peak demand condition, so the average cost of the required efficient infrastructure to supply that demand is used for charging calculations. Energy valuations are only needed for the purpose of calculating distribution losses to be paid by demand.

In China, there is no locational pricing. However, for the generation side, a benchmark price system is used to determine the price of newly installed generators.

What Cost Allocation Methods Are Used in Your Charging Methodology?

In the United Kingdom, for EHV networks the LRIC charging model allocates long-run incremental costs based on the distance of the traveling paths and the degree of their utilization for power injection and withdrawal at every single node of the system. For FCP the allocation of future cost is averaged within each network group. At the HV/LV level, the DRM charging model allocates years-ahead cost based on postage stamp.

In Brazil, inside each voltage level the allocation is based on the postage stamp. Among the voltage levels, the LRIC is used for allocating the allowed revenue.

In India, the network cost allocation is based on the cost-of-supply principle. The network costs are initially classified based on the type of costs involved—that is, whether they are demand, energy, or customer related. These costs are allocated on the basis of contribution of individual customer categories on each type of cost. Actual customer costs are a reflection of the proportion of the number of customers connected to the system in each category. The electricity price is similar throughout the state for a given customer category. The pricing scheme is very close to a postage stamp method.

In Germany, all network costs are socialized. The network charge is a postage stamp in each voltage level. Only load pays the charge; the generation charge is zero. Distance between feed in and consumption is irrelevant. There is regional differentiation because the charges are calculated for each network of which there are some 900. Cost from higher voltage levels is passed on to lower levels and finally to consumers.

In Spain, as in Brazil and Germany, a postage stamp method is implemented inside each voltage level. The distance between generation and consumption is irrelevant.

In Chile, a postage stamp scheme is used inside each voltage level, with differences only arising depending on the density of the area served and whether networks are underground or overhead.

Is Demand Treated the Same as the Generation? If Not, Why They Are Treated Differently?

In the United Kingdom, LRIC treats demand the same as generation. Both are examined for how they will impact the present value of future reinforcement at each node of the EHV network. For FCP and DRM, demand and generation are treated differently. The FCP generation charge is based on statistical generation growth, which is lumpy in nature, and its cost allocation is based on average cost pricing. The FCP demand charge is based on gradual demand growth, and its cost allocation is based on a marginal approach. The

table 2. A summary of cost drivers and allocation methods in the distribution pricing structure.							
		United Kingdom	**Germany**	**Spain**	**Brazil**	**Chile**	**India**
Cost drivers	Geographical location	Yes—EHV No—HV/LV	No	No	Yes—EHV	No	No
	Voltage level	Yes	No	Yes	Yes	Yes	No
	Density	Yes—EHV No—HV/LV	No	No	No	Yes	No
	Asset types (underground or overhead)	Yes—EHV No—HV/LV	No	No	No	Yes	No
	Tariff differentiation between differing DNOs	Yes	Yes	No	Yes	Yes	No
Cost used	Embedded cost	HV/LV	N/A	No	N/A	No	Yes
	Marginal cost	N/A	No	No	EHV—generator	No	N/A
	Incremental cost	EHV, locational (LRIC, FCP—demand) EHV, (FCP—generation)	New investment cost is socialized on case-by-case basis	No	HV/LV: ratio of future investment costs and load growth in present value	Yes	N/A
	Average cost based on historical expenditure	HV/LV	EHV/HV/LV	No	N/A	Yes	N/A
	Cost-causality principle	No	No	Cost allocated to cost drivers, time periods and consumers according to cost causation	No	No	No
Cost allocation method		HV/LV—postage stamp EHV—LRIC—distance of traveling path EHV—FCP—average within each group	Postage stamp	Postage stamp	EHV—ICRP (generator only) HV /LV—postage stamp	Postage stamp	Principle of cost-of-supply, similar to postage stamp
Boundaries between connection and use charges	Connection charge	Yes—shallow	Yes—shallow	Yes—shallow (consumer), deep (generator)	Yes—shallow	Yes—demand only if more than 100 m away	Yes—shallow (demand), deep (DGs)
	UoS charge	Yes—all users	Yes—consumer only	Yes—all users	Yes—all users	Yes—all users	Yes—consumer only
	Reinforcement charge	Yes—reinforcement required one voltage level above connection	Yes—load and generator not from renewable energy or pit gas	N/A	N/A	Yes—generator	N/A

The electricity supply industry is undergoing a transformation to promote greater interactions between network users and the grid.

DRM was designed for a passive network: both generation and demand are considered to require network upgrading, so both are charged for the use of the network.

In Brazil, the consumption side is based on the LRIC for each voltage level. There is a locational signal for generators connected at 138 and 88 kV based on the investment cost related price (ICRP). For lower voltages, the generation tariff is based on the regional average charges applied to all consumers.

In India, for the central transmission utility, generally there are no network charges levied on generation utilities. All the network revenue is recovered from demand customers. The present pricing structure evolves from that existing during integrated market environment, wherein the thrust of the approach was to recover the revenue incurred. As all the utilities were government owned, the necessity for charging generation utilities was never felt. The present charging structure is a reminiscent of those existing during those times, and are still evolving. As far as the state transmission utilities are concerned, the charges are restricted to connection charges only. Usually, the generation utility is expected to make arrangements for connection to the network utility. The DGs are generally not connected at lower voltages associated with state distribution utilities. Thus, at present the question of similarity is not relevant for distribution networks.

In Germany, generators do not pay UoS charges; they only pay for connection to the next grid connection point. Load customers pay a two component fee: an annual fee in ct/kWh related to the maximum capacity consumed during the year and an energy fee in cent/kWh related to the energy consumed. Additionally, *Baukostenzuschüsse*, as defined earlier are allowed to recover necessary reinforcement costs for connection of load or generation. Generators in the distribution network have to be compensated for avoided cost-of-network charges at higher voltage levels unless they are subsidized via a feed-in-tariff (renewable energy feed-in-tariff or combined heat and power [CHP] law). The main reason for this is to promote DG.

In Spain, until 2011 generators did not pay UoS charges. Currently, they pay a €0.5/MWh flat UoS charge, for all the generators connected to transmission and distribution networks. They also pay a charge for connection to the grid. Load customers pay, besides a connection charge, a three component tariff as UoS charge: a fixed charge, in €/month; a capacity charge according to their contracted power, in €/kW·month; and an energy charge, in €/kWh.

In Chile, the distribution company has the right to receive remuneration for all its installations, based on the efficient network model; thus, all users have to pay for the utilization of the network, including both demand and generation. However, network charges for generators have had limited application, as discussions often arise about the need to reinforce networks when a new injection is being incorporated into the distribution network.

A summary of the differences among network pricing structures is shown in Table 2.

What Approaches Are Used for Revenue Reconciliation?

In the United Kingdom, LRIC, FCP and DRM use fixed adders to minimize the distortion to charges generated from the charging methodologies. This is to be reconsidered by the industry, as pockets of the network see very large scaling.

In Brazil, if the application of the LRIC for each voltage level is not enough, multiplied adders are used to match the required revenue.

In India, the complete network costs are reflected and recovered by the usual network pricing models. Hence, revenue reconciliation is not required.

In Germany, network costs are reflected in the calculation of charges, which are regulated by a revenue cap. At the end of a calculation period, network companies have to compare real revenues from network charges to allowed revenues. Insofar as pass-through costs are concerned, a comparison of realized cost and cost factored into the network tariffs is carried out. Differences are included as cost-reducing or cost-increasing factors in future calculations. The DG compensation for avoided network charges presses on the revenues at transmission level. This is beginning to become a problem.

In Spain, as in India, the total distribution costs are reflected and recovered by the used-pricing methodology. Hence, revenue reconciliation is not necessary.

In Chile, distribution costs of the efficient model company are reflected and recovered in the pricing methodology, and real companies will have enough revenues, or not, depending on how far they are from the benchmark. No revenue reconciliation is considered.

Are Your Charges Set for Annual Use-of-System or for Some Other Periods? Is There Any Time Period Tariff?

In the United Kingdom, all charges calculated from the network charges are annual charges. They are then converted into hourly charges based on customers' load factor and coincident factor. At present, the United Kingdom

> Post-2007, the United Kingdom and Brazil lead the way in introducing locational charges at the EHV distribution level.

offers two band tariffs: one is normal tariff and the other is economic, where companies offer cheaper rates for energy usage at off-peak periods. Different companies have slightly different time band for off-peak times.

In Brazil, for voltage levels from 138 to 13.8 kV, there are a set of time-of-use tariffs, whereas for low voltages there are only the flat tariffs. The tariffs are set by the regulatory agency for each distribution company according to their time band for peak and off-peak.

In India, the UoS charges are usually set on an annual basis. Some tariff structures for high-valued customers do reflect a time-period based tariff, taking into account seasonal impact.

In Germany, charges are set annually. Apart from the usual network tariffs, special rates can be negotiated; however, they have to be offered as choices to all customers (nondiscrimination). Charges for load are differentiated by the typical annual utilization hours. Furthermore, charges make up a component related to peak load of customers. Factoring in a coincidence factor serves to distribute costs based on contribution of individual users to system peak.

In Spain, UoS charges are calculated using an annual basis. At present, LV customers can choose between a flat tariff, a tariff with two time periods, and a tariff with three time periods. MV customers can choose between a three-time period tariff and a six-time period tariff, while EHV customers have a tariff with sixtime periods.

In Chile, distribution charges are calculated every four years, on an annual basis, depending on peak demand of customers, as related to system peak demand. They correspond to capacity payments reflecting capacity use of installations; energy charges are only related to system losses. Customers may choose how their peak demand is measured, and different tariffs exist depending on the metering scheme used. System peak demand occurs within certain hours of the day and in certain months of the year, so that customers may adapt their consumption to reduce their capacity payment.

In China, there is a set peak-valley and time-of-use price as well as seasonal power price for nonresidential users. There have been some pilot projects of peak-valley and time-of-use price for residential users in some provinces, such as Shanghai and Zhejiang, but most residential users have a flat tariff.

figure 5. A large penetration of photovoltaic generation in the urban parts of the United Kingdom. (Source: Western Power Distribution, United Kingdom.)

Is There Any Specific Tariff for Distributed Generation or Microgeneration Such as a Feed-in Tariff?

In the United Kingdom, for distributed generation larger than 5 MW, there is a renewable obligation certificate on the top of energy sale. DGs have to pay for the UoS and connection charges themselves. For distributed or microgeneration below 5 MW, at present prices are negotiated with the local supplier; most will receive a floor price that is delinked from the price variation in the energy market. Since April 2010, small-scale generators receive a feed-in tariff that provides greater certainty on the return on investment in the event that they make their machines function.

table 3. A summary of the distribution pricing structure.

	United Kingdom	Germany	Spain	Brazil	Chile	India
Retail market—Consumers can choose their own supplier	Yes	Yes	Yes	Yes—but only if demand ≥ 3 MW	Yes—but only if demand ≥ 2 MW	Yes—restricted consumers
Charges set for annual use of the system	Yes—further converted into hourly charges	Yes	Yes	Yes	Yes	Yes
Time period tariff	Peak and off peak	Time-differentiated tariff for consumer over night	LV—flat tariff, two or three time periods MV—three or six time periods EHV—six time periods	EHV/MV—time of use LV—flat tariffs	Flat tariffs	Flat tariffs, except for high-value consumers
Specific tariff for distributed generation (feed-in-tariff)	Yes—renewable obligation certificate	Yes—avoided network charges of higher voltage levels	Yes—flat feed-in-tariffs and UoS charges for DG	Yes—locational tariff only for generation connected to 138/88 kV	No	Yes—subsidization of wheeling charges and energy banking

In Brazil, since 2009 a locational tariff has been set to generation connected to 138 and 88 kV networks. Other generations embedded at the distribution grid pay an average consumer tariff.

In India, renewable energy is predominantly available in the form of distributed generation. To promote renewable generation, a two-pronged strategy via demand and supply has been adopted. On the demand side, accounting for specific resource availability, state electricity regulatory commissions require distribution utilities to purchase a minimum percentage (from 2 to 10%) of renewable energy. On the supply side, competitive bidding has been set as the preferential route for renewable power purchase, but because there are few renewable power developers, encouraging rates are not being offered. The subsidization of wheeling rates and energy banking has also been offered to encourage renewable power. The central electricity regulatory commission is also contemplating free-wheeling for renewable power on an interstate transmission network, to allow access to the highest-paying bidder.

In Germany, distributed generation is recompensed for avoided transmission network charges, which are avoided by feeding into the distribution network. Renewable generation receives a feed-in tariff. The level of the tariff is dependent on technology and the size of the generator.

In Spain, renewable generation and CHP receive a feed-in tariff, depending on the technology and the size of the generator, although recently these tariffs have been reduced and, in some cases, eliminated. These incentives are updated by the regulator and are the same for all the generators in Spain; there are no locational signals. As mentioned, DGs pay a flat € 0.5/MWh UoS charge.

In Chile, there is no feed-in tariff for any generation. As of 2010, a minimum nonconventional renewable energy quota requirement was set for contracts, including all renewables except hydro generation over 20 MW, starting from 5% and growing to 20% by 2025. While exception of transmission wheeling tariffs is given to this energy, no exception is made for distribution charges.

In China, there is no specific tariff for distributed generation or microgeneration.

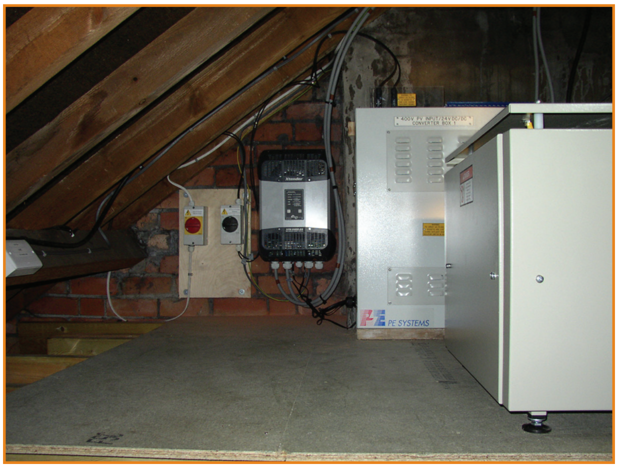

figure 6. Completed installation for home-area energy storage to work together with photovoltaic generation and a local DC network. (Source: Western Power Distribution, United Kingdom.)

> Major advances have already been made in Europe and South America in reforming distribution pricing and tariff structures to meet low carbon requirements.

A summary of the differences among tariff structures is shown in Table 3.

Conclusions

Major advances have already been made in Europe and South America in reforming distribution pricing and tariff structures to meet low carbon requirements. The advances made (the United Kingdom and Brazil, in particular) are to facilitate the economic connection of renewable energies, to maximize the use of the existing system, and to encourage the growth of efficient and renewable generation at all voltage levels. The advances can be summarized as follows:

- ✔ Introducing locational UoS charges to encourage the appropriate location of new generation and demand and facilitate cheaper connection of efficient and renewable energies
- ✔ Introducing better alignment between transmission and EHV distribution network charging methodologies and discourage uneconomic DG migration
- ✔ Introducing new performance based revenue control, ensuring that customers to pay a fair price for rewiring a smart distribution system.

These advances represent step changes to distribution regulation, pricing, and tariff structures, which have had very little linkage with the state of the system in the past 20–30 years. These advances are targeted to support the efficient integration of distributed generation, particularly those DGs of a renewable nature at EHV levels. Those advances, however, are not designed for the extensive MV/LV network, as is photovoltaic generation shown in Figure 5, nor are they designed for promoting demand-side participation to maximize operation efficiency and reduce investment cost, as Figure 6 illustrates.

The move to a low-carbon energy system within a smart-grid environment requires active demand side participation; users should play a key role in balancing intermittent generation and reducing network constraints. This is a structure that places operational cost at the heart of the pricing and tariff structure, that can incentivize active generation/demand interactions at all voltage levels while also reducing network fixed costs. The main challenge is how to assess and allocate future network costs that encourage the right balance between network investment, performance, and risks.

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